Dynamics and Energy Scaling of Granular Explosion Cratering

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INTRODUCTION

Granular Cratering

Granular cratering is a ubiquitous phenomenon that occurs in diversified natural and industrial contexts. There are two major categories in granular cratering, namely impact-induced cratering and explosion-induced cratering. The impact-induced cratering has been well studied due to its relevance to asteroid impact craters formed by the hypervelocity impact of bodies, such as Meteor Crater on Earth. In Professor Cheng research group, liquid drop impacts, such as raindrop on granular materials, were investigated and a quantitative similarity was found between liquid drop impacts and asteroid strikes in terms of the energy scaling and aspect ratio of craters. In comparison, very few experiments have been conducted to explore explosion-induced granular cratering through air blast processes.

An interesting fact about explosion-induced cratering is that Hooke was the first one who claimed the craters on the Moon may be left when some air bubbles trapped inside the body rose up.

Figure 1. Side view of the Moltke crater taken from Apollo 10.[1]

OBJECTIVES

- Study the dynamics of explosion-induced cratering
- Compare high-energy vs. low-energy explosion cratering
- Compare explosion vs. impact cratering
- Start with a quasi-two-dimensional system
- Construct a three-dimensional setup

MATERIALS & METHOD

- A quasi-two-dimensional Hele-Shaw cell (36” × 36” × 0.15”) with a fast-response valve
- Front panel: transparent glass plate
- High-speed camera (1000 fps)
- Granular particles: 90 µm soda-lime glass beads
- Three parameters: burial depth (d_b), pressure (P), and duration (t_b)
- Controlled by MATLAB code
- Venting valves at bottom combined with a leveler to reset the granular bed

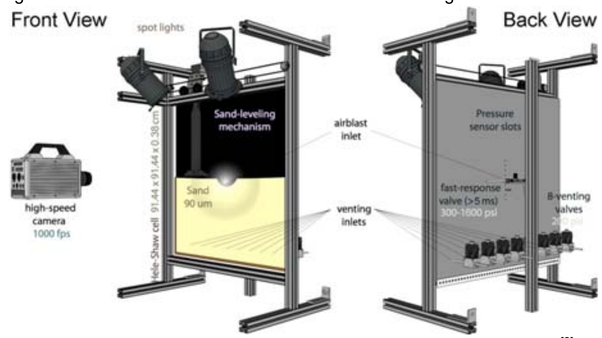

Figure 2. Schematic showing the quasi-two-dimensional experimental setup.[2]

RESULTS & DISCUSSION

- **Bubbling vs. Eruption**

  We defined two regimes of the dynamics of explosion cratering – bubbling regime and eruption regime based on the different trends of maximal width of an air bubble.

Bubbling Regime $t_b = 5$ ms

Transition $t_b = 31$ ms

Eruption Regime $t_b = 107$ ms

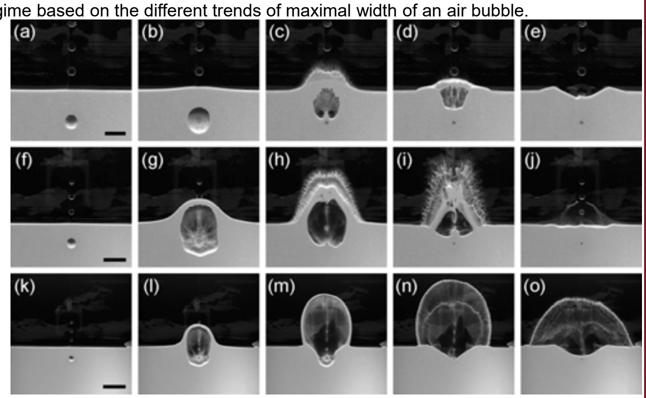

Figure 3. Snapshots from high-speed videos showing explosion cratering at different duration with a constant pressure P=800 psi and burial depth d_b=1.25”. Scale bar : 2 inches.[2]

- **Morphology of explosion craters: Hyperbolic**
- **Energy scaling**
  - Rim-to-rim diameter of craters, $D_r \sim E^{1/3}$ in the bubbling regime
  - Depth of craters, $d \sim E^{1/2}$

CONCLUSIONS

Using high-speed photography, the fast dynamics of explosion processes are imaged. We define bubbling and eruption regimes of explosion cratering. The crater profiles can be fitting with hyperbolic functions regardless of what regime is. Similar observation was found using different explosion mechanisms.[3] The rim-to-rim diameter and depth of craters are increasing with energy. Especially the power-law scaling of rim-to-rim diameter with energy is similar to that of scaling of higher energy explosion and low-energy explosion with black powders.[3]

NEXT STEPS

- Trigger air blast processes in a three-dimensional setup
- Study the size and depth of craters
- Compare three-dimensional explosion cratering vs. impact cratering (liquid or solid drop impact)
- Investigate dynamics of explosion cratering using high-speed imaging

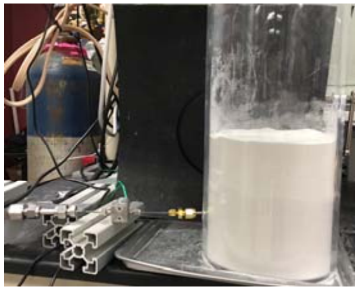

Figure 4. Picture of the current three-dimensional set-up.

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[3] Pacheco-Vazquez, F.; Tacuma, A.; Marsto, JO. Craters produced by explosions in a granular medium. *Phys Rev E.* 2017;96:032904.

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